JOURNAL OF BALTIC SCIENCE EDUCATION

ISSN 1648-3898 /Print/
ISSN 2538-7138 /Online/

ADVANCING GENDER EQUITY IN STEM EDUCATION: THE ROLE OF INQUIRY-BASED COOPERATIVE LEARNING AND CLASSROOM ENGAGEMENT IN CHALLENGING GENDER ROLE STEREOTYPES

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Abstract. *Global gender gaps in Science, Technology, Engineering, and Mathematics (STEM) fields persist, as female students often encounter cultural and academic barriers that constrain their involvement and success. This study attempts to examine the mediating and moderating roles of classroom engagement and inquiry-based cooperative learning in the association between gender role stereotypes and STEM academic performance with a unique sample of 366 upper-secondary girls in underprivileged areas of China. This study employs a quantitative methodology, using survey data and structural equation modelling (SEM) to examine the mechanisms and pathways among the key variables. The results indicated that: (1) gender role stereotypes had a significantly negative effect on STEM academic performance; (2) classroom engagement played a mediating role between gender role stereotypes and STEM academic performance; and (3) inquiry-based cooperative learning played a moderating role in the path of female gender role stereotypes to STEM academic performance. This research sheds light on how classroom environment affects gender role stereotypes and STEM success, affecting educational policy and training. When encouraging inquiry-based and cooperative learning, educators and policymakers should address gender and individual learning requirements.*
Keywords: *gender role stereotypes, classroom engagement, STEM academic performance, inquiry-based cooperative learning, structural equation modelling*

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Introduction

STEM (Science, Technology, Engineering, and Mathematics) education has emerged as a crucial foundation for national competitiveness and innovation in the digital age. Since countries become more reliant on advances in technology, STEM fields serve as key drivers for prosperity and social progress (Murad et al., 2022). The World Economic Forum (2023) forecasts a significant talent shortage in STEM fields, especially in engineering and technology, resulting in over 85 million unfilled positions by 2030 and a potential economic loss of $8.5 trillion globally. The fact that women will only constitute 28% of the STEM workforce in 2023 is even more worrisome (UNESCO, 2024). This disparity is evident in China, where women account for only 26.27% of the R&D workforce and just 5.79% of the Chinese Academy of Sciences and Engineering academicians; moreover, only 7.38% of newly elected academicians in 2021 were women, proving the extreme under-representation of women in STEM fields (National Bureau of Statistics of China, 2022).

Gender stereotypes, notably a belief that women are less talented in mathematics and science, are one of the most frequently acknowledged explanations for this occurrence (Boivin et al., 2024). Research in western contexts has repeatedly shown how these preconceptions affect girls' academic performance in STEM fields (Fiedler et al., 2024), with similar patterns identified in China (Luo & Chen, 2024). This aligns with Bandura's (1977) self-efficacy theory, which suggests that gender stereotypes that undermine girls' confidence could affect their achievement in STEM fields (Fiedler et al., 2024).

Many interesting studies have considered different aspects of gender stereotypes in STEM education; however, few gaps are addressed in this study. First, most existing related research, however, overlooks the more general impact of gender stereotypes on students' educational perspectives

https://doi.org/10.33225/jbse/25.24.1101

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

and decision-making while concentrating on subject-specific preconceptions, particularly stereotypes related to math and science (González-Pérez et al., 2020). Beyond mere intellectual ability, gender role stereotypes (GRS) impact society's expectations, traditionally portraying women as caregivers and men as suitable for STEM jobs (Priyashantha et al., 2023). These social conventions shape females' self-perceptions, job paths (Silberstang, 2011), and educational goals, therefore either directly or indirectly influencing their academic performance by lowering their determination and dedication to STEM learning (Tandrayen-Ragoobur & Gokulsing, 2022).

Second, academic performance and retention rates of students have been proven for years to be mainly contingent by classroom engagement (Hill & Wang, 2015). Classroom engagement (CE) refers to learners' active involvement in the learning process across four dimensions: behavioural, emotional, cognitive, and agentic (Reeve, 2013). Active and continuous engagement in subjects related to STEM not only improves academic achievement but also encourages female students to identify with the scientific role (Starr et al., 2020). Further, highly engaged students generally show great intrinsic motivation, which fuels their curiosity in learning novel knowledge and results in major time and effort investment (Appleton et al., 2006). Evidence from various contexts, including U.S. (Del Toro & Wang, 2023), Russia (Maloshonok, 2022), and Belgium (Van Houtte, 2023), confirms that stereotypes adversely impact learners' self-perceptions, thereby limiting their active participation in classroom activities, especially in STEM field. These findings collectively reveal a mechanism by which stereotypes indirectly affect academic outcomes by affecting student engagement, a pathway that has received little empirical attention in prior research.

Third, according to social cognitive theory (SCT) (Bandura, 1986), which highlights the effects of environmental factors such as instructional approaches on individual beliefs and motivations that influence academic behaviour, and constructivist learning theories (Vygotsky & Cole, 1978), which emphasize the significance of social contexts in knowledge construction, this study considers the moderating role of inquiry-based cooperative learning (IBCL). IBCL focuses on active problem exploration with cooperative team learning and is widely implemented in STEM fields, especially in mathematics, science, and engineering education (Gillies, 2023; Ješková et al., 2022; Mafarja et al., 2024). Empirical studies consistently show that IBCL benefits academic outcomes, including advancements in students' critical thinking (Suprijono et al., 2025), problem-solving skills (Soomro et al., 2025), and interest in learning (Wang et al., 2021), and sense of self-efficacy in STEM learning settings (Liu & Wang, 2022). Engaging students in open-ended enquiry tasks and supporting peer-to-peer interaction enhances conceptual understanding and promotes sustained engagement with STEM subjects in IBCL (Nguyen & Oanh, 2025). Additionally, IBCL is currently receiving significant attention as an effective pedagogical method that promotes active engagement and enhances educational outcomes in STEM fields. Despite this, its potential moderating roles in the correlation between GRS, CE, and STEM performance remain predominantly unexamined.

Moreover, previous studies have shown that GRS are dynamic instead of fixed, emerging early in childhood and shaped by family, social expectations, educational systems, and cultural contexts (King et al., 2021). A gender-inclusive and supportive classroom setting may stimulate a sense of belonging in girls (Sultan et al., 2024), further improve their motivation and interest (Casey et al., 2023), and ultimately affect their STEM academic performance.

In a summary of the above explained issues, despite the increasing global awareness of gender equity in STEM education, most of the existing research has primarily concentrated on Western or urban populations, resulting in a limited knowledge of how GRS interact with classroom dynamics in disadvantaged contexts. Meanwhile, previous research has thoroughly investigated the direct impact of gender stereotypes regarding abilities in science and mathematics on girls' attitudes and performance in STEM fields. Nevertheless, the understanding of GRS, as well as the mechanisms and contextual conditions that underlie these effects, remains insufficient. The role of classroom processes, specifically CE and IBCL, has been underexplored empirically, regardless of their potentially significant impact on the translation of gender-related beliefs into academic outcomes.

Addressing these gaps results in a more thorough comprehension of the interaction between societal beliefs and instructional practices in shaping girls' STEM achievements. This is essential for fostering equitable participation in STEM and for aligning gender-sensitive pedagogy with the ongoing shift towards student-centred education. It enhances theoretical understanding of gendered learning processes and offers practical strategies for promoting inclusive and effective STEM education. Beyond the educational context, it supports global initiatives aimed at reducing gender disparities and advancing the United Nations Sustainable Development Goals on Quality Education (SDG 4) and Gender Equality (SDG 5) (UN, 2016).

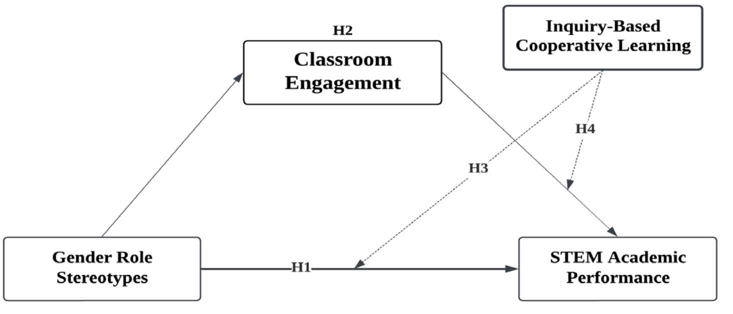
To address these gaps, this study proposes an integrated model based on SCT (see Figure 1), with an emphasis on how the IBCL moderates the associations between GRS, CE, and STEM academic performance. A quantitative design was employed, collecting questionnaire data from Chinese upper-secondary female students and analysing it with SEM. This study makes several significant contributions. First, it closes a major gap in the literature by

https://doi.org/10.33225/jbse/25.24.1101

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

providing empirical evidence regarding the theoretical correlation between GRS and STEM academic performance. Second, it provides a fresh understanding of whether educational improvements in economically deprived areas are successful or whether they may result in unanticipated negative implications, revealing the moderating role of the IBCL. Third, drawing on the research results, the study suggests centred strategies to optimise classroom settings and mitigate potential adverse effects on females' STEM academic performance, while also stimulating their interest and involvement in STEM fields.

Figure 1
Conceptual Framework of the Study



Based on the above discussion, the present study proposes the following hypotheses:

H1: GRS have a significant effect on the STEM academic performance of upper-secondary girls.
H2: CE mediates the association between GRS and STEM academic performance.
H3: IBCL moderates the association between GRS and STEM academic performance.
H4: IBCL moderates the association between GRS and STEM academic performance through CE among female students.

Research Methodology

General Background

This study used a quantitative, cross-sectional design, which is appropriate for testing hypothesised structural associations among variables (GRS, CE, IBCL, and STEM academic performance) at a single point in time (Creswell & Creswell, 2018). Data were collected from seven public upper-secondary schools in Shangluo City, an underdeveloped region in western China, between January and March 2025, using a structured questionnaire. Validated scales were employed for each construct. SEM was conducted in AMOS using maximum likelihood estimation with 5,000 bootstrap resamples to examine the hypothesised direct, mediating, and moderating effects. Ethical approval for this research was obtained from the relevant institutional ethics committee, and informed consent was obtained from all participants and their parents or guardians.

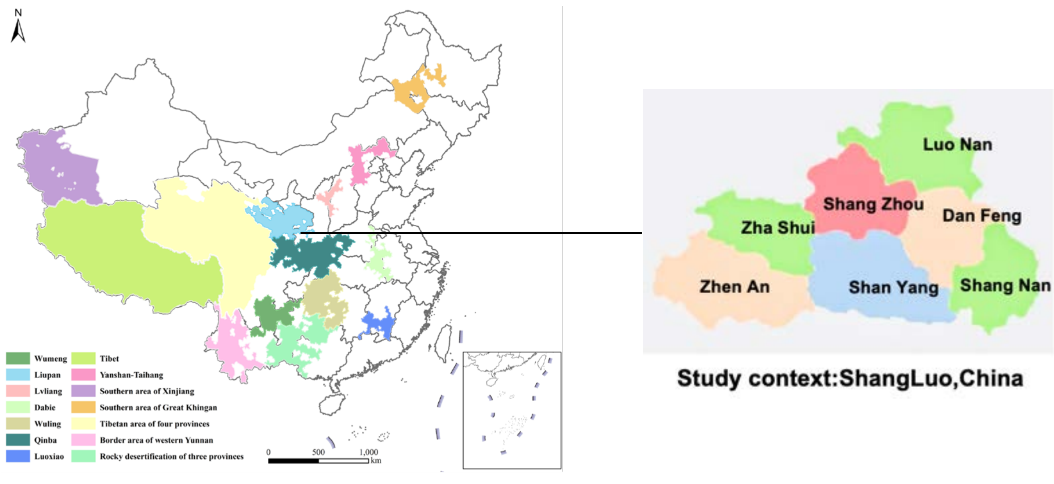
Participants

Based on the Outline of China's Rural Poverty Alleviation and Development (2011–2020), China's poverty-stricken areas were classified into 14 contiguous regions of dire poverty, involving 680 counties nationwide (see Figure 2) (National Bureau of Statistics of China, 2021). Shangluo City was selected as the research site due to its high representativeness within these designated regions. As one of the 14 deeply impoverished contiguous areas, Shangluo comprises 7 counties and districts, all of which have been designated as national-level poverty-stricken areas.

https://doi.org/10.33225/jbse/25.24.1101

Journal of Baltic Science Education, Vol. 24, No. 6, 2025
ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 2
14 Contiguous Poverty-Stricken Areas in China and Location of the Study



Upper-secondary schools in China are generally categorized into key upper-secondary schools and regular upper-secondary schools based on overall academic performance and resource allocation (MOE, 2022). STEM subjects (mathematics, physics, chemistry, and biology) are mandatory in China, while integrated STEM curricula remain uncommon, primarily offered as school-based elective courses in a limited number of institutions.

Given the disparities in educational resources and quality across regions, this study focused on Grade 10 female students from public upper-secondary schools in Shangluo City, Shaanxi Province, a nationally recognized poverty-stricken area. The target population comprised approximately 8,000 female students from 16 upper-secondary schools distributed across Shangzhou District, Luonan County, Danfeng County, Shangnan County, Shanyang County, Zhen'an County, and Zhashui County (Statistics Bureau of China, 2024). Using Cochran's formula with a 95% confidence level and a 5% margin of error, the required sample size was determined (Cochran, 1977). A multistage stratified random sampling method was then applied: one public high school was selected from each of the seven counties, and Grade 10 female students were proportionally and randomly chosen. After data screening, 366 valid responses were retained, ensuring both representativeness and feasibility.

Instrument and Procedures

The study measured key variables with four validated instruments. To ensure objectivity and accuracy, STEM academic performance was operationalized using the Cumulative Grade Point Average (CGPA) from students' end-of-term exam scores in mathematics, physics, chemistry, and biology from school records (Apkarian et al., 2021). GRS were assessed using the 12-item Adolescent Women's Attitudes toward Women Scale (Galambos et al., 1985), which reverse scored chosen items to indicate less traditional stereotypes. The Classroom Engagement Scale (Reeve & Lee, 2014) measured behavioural, emotional, cognitive, and agentic engagement. Two subscales (cooperation and investigation) from the What Is Happening in This Class? (WIHIC) questionnaire (Fraser, 1998) examined students' collaborative and inquiry-oriented learning experiences. All self-report measures used a 5-point Likert scale and have been assessed across multiple educational contexts, proving their reliability and applicability.

A questionnaire was developed and sent online using the widely used survey tool So Jump (2025) in China. Before participation, the students' legal guardians as well as themselves signed informed permission. Participants were guaranteed that their answers would remain confidential and that this data would be applied only for academic research purposes. 504 responds in all were first gathered. Following quality control strategies, such as eliminating replies with too short completion durations or those displaying patterned responses (i.e., similar ratings across items), a final sample of 366 valid responses was selected for this study. Table 1 presents a detailed description of the demographic characteristics of the participants.

https://doi.org/10.33225/jbse/25.24.1101

ISSN 1648–3898 /Print/
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Table 1
Samples' Demographic Characteristics (n=366)

Demographic variable	Residence			χ^2 (df)	p
	Urban (140)	Rural (226)	Total (366)		
Nationality				3.188 (1)	.074
Han	68.6% (96)	59.3% (134)	62.8% (230)		
Minority	31.4% (44)	40.7% (92)	37.2% (136)		
Age				0.365 (2)	.833
13-14years old	1.4% (2)	1.8% (4)	1.6% (6)		
15-16years old	96.4% (135)	95.1% (215)	95.6% (350)		
17-18years old	2.1% (3)	3.1% (7)	2.7% (10)		

Data Analysis

The data analysis comprised two stages: (1) evaluation of the measurement model and (2) analysing the structural model through path coefficients and *p*-values. The measurement and structural models were estimated utilizing AMOS version 26. Prior research indicates that AMOS-SEM can be particularly effective for examining correlations among latent constructs assessed through multiple indicators, and it is especially suitable for studies with large sample sizes ($n > 250$), making it appropriate for this research (Sarstedt et al., 2017). The measurement model was evaluated based on model fit indices**,** item loadings**,** Cronbach's alpha, and composite reliability, following the recommendations of Hair et al. (2019). After estimating the model (see Table 2**)**, the final measurement model exhibited a good fit with the data, ensuring its validity and reliability for subsequent structural analysis.

A pilot study was implemented with 50 female upper-secondary students sharing characteristics with the target population to assess the feasibility of the instruments and analytical techniques (Baker, 1994). Participant feedback led to modifications of the questionnaire, and reliability was evaluated using Cronbach's alpha in SPSS 26. All constructs exceeded the .70 level (Cochran, 1977), indicating satisfactory internal consistency (refer to Table 3).

Table 2
Research Measurement Model Fit

Fit index	Recommended value Hair et al., 2019	Result	Interpretation
χ^2	Non-significant at $p < .05$	466.348	Good fit
Degrees of freedom (df)	n/a	219	Good fit
χ^2/df	< 5 preferable < 3	2.129	Good fit
Goodness-of-fit index (GFI)	> 0.90	.903	Good fit
Adjusted Goodness-of-fit index (AGFI)	> 0.80	.877	Good fit
Comparative fit index (CFI)	> 0.90	.949	Good fit
Root mean square residuals (RMSR)	< 0.10	.0418	Good fit
Root mean square error of approximation (RMSEA)	< 0.08	.056	Good fit
Normed fit index (NFI)	> 0.90	.908	Good fit
Incremental Fit Index (IFI)	> 0.90	.949	Good fit

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ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Table 3
Pilot Study Cronbach's Alpha Value for the Instruments (n=50)

Construct	Number of items	Sample Items	α
Gender Role Stereotypes (AWSA)	12		.821
Behaviour and authority	3	Swearing is worse for a girl than for a boy	.705
Education and career	4	Boys are better leaders than girls	.827
Capability and responsibilities	5	On the average, girls are as smart as boys	.835
Classroom Engagement (CES)	12		.924
Behavioural	3	I try my best in the class	.861
Cognitive	3	I try to find the best way for an assignment before working on it	.789
Emotional	3	I feel nice when I am in class	.869
Agentic	3	During the class, I raise questions to facilitate learning	.857
Inquiry-Based Cooperative Learning (WIHIC)	16		.950
Investigation	8	I am asked to think about the evidence for statements	.967
Cooperation	8	I work with other students on projects in this class	.933

This study utilized AMOS to perform confirmatory factor analysis (CFA) for assessing construct validity. Convergent validity was evaluated by average variance extracted (AVE) and composite reliability (CR), revealing all CR values surpassing .70 and most AVE values exceeding the .50 threshold (Hair et al., 2019). Given that the AVE for GRS is marginally below .50, Fornell and Larcker (1981) claim that high CR values still indicate sufficient validity. All factor loadings were statistically significant ($p < .001$), therefore confirming the validity of the measurement model (refer to Table 4).

Table 4
Construct Reliability and Validity

Construct	Items	Factor Loadings	CR	AVE	GRS	CE	IBCL
Gender Role Stereotypes	Behaviour and Authority	.658	.703	.4426	.665		
	Education and Career	.728					
	Capability and Responsibility	.604					
Classroom Engagement	Behavioural	.772	.9187	.74	-.171**	.86	
	Cognitive	.887					
	Emotional	.969					
	Agentic	.799					
Inquiry-Based Cooperative Learning	Investigation	.814	.7871	.6489	-.219**	.792**	.806
	Cooperation	.797					

Notes: Factor correlation matrix with the square root of AVE on the diagonal.

https://doi.org/10.33225/jbse/25.24.1101

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Research Results

Direct Effect

SEM was employed to examine the direct effect of GRS on STEM academic performance. Table 5 displays the path analysis results, with model fit indices calculated by the maximum likelihood method. The model indicated a satisfactory fit (CMIN = 34.648, *df* = 12, CMIN/DF = 2.887, $p < .001$, GFI = .974, AGFI = .939, NFI = .906, IFI = .936, CFI = .935, SRMR = .056, RMSEA = .072, PClose = .089), meeting the recommended thresholds for goodness of fit.

The path analysis results support H1, showing a significant negative correlation between GRS and STEM academic performance ($\beta = -.206$, $p < .05$). Specifically, a one standard deviation increase in GRS correlates with a .206 standard deviation decrease in STEM performance. It indicates that increased adherence to GRS adversely affects girls' academic performance in STEM, underscoring the harmful effects of gender-related biases on their educational outcomes.

Table 5
The Summary of Direct Effect of the Path Model

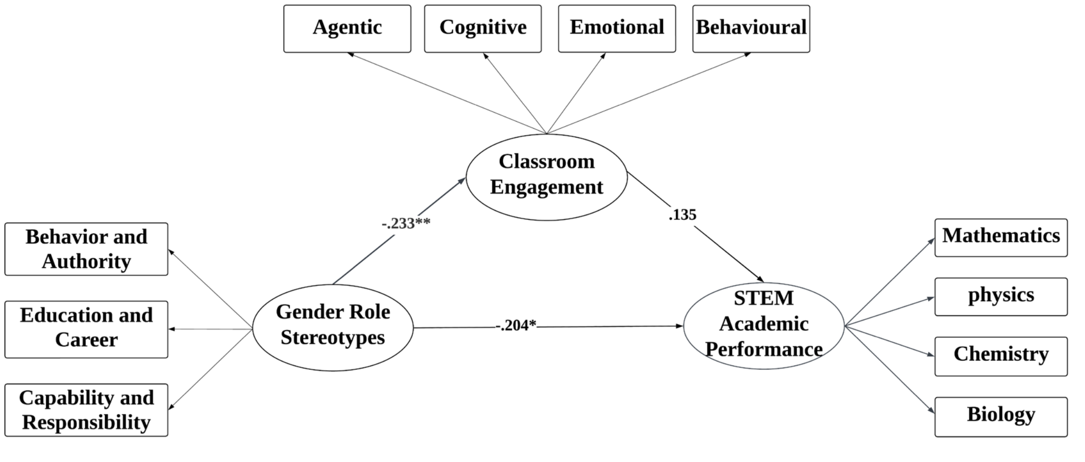
H#	Proposed Correlation	*B*	*β*	*S.E.*	*C.R.*	*p* Value	Study Results
H1	STEM.AP. <----GRS	-.771	-.206	.376	-2.052	.040	Supported

Notes: B = Unstandardized Regression Weight Estimate; = Standardized Regression Weight; S.E. = Standard Error; C.R. = Critical Ratio; = Significance Value.

Mediation Effect of Classroom Engagement

The mediation model for the present study is shown in Figure 3. The model fit reveals CMIN = 111.996, *df* = 40, CMIN/DF = 2.799, *p* =.000, GFI = .949, AGFI = .915, NFI = .897, IFI = .932, TLI = .905, CFI = .931, SRMR = .053, RMSEA = .070, and PClose = .016. The model seems appropriate and has satisfied the goodness-of-fit criteria based on this result.

Figure 3
Mediation Model for the Study



In the direct path model, GRS has a direct negative significant effect on STEM academic performance ($\beta = -.204$ and $p = .038$). When the mediating effect of CE is included, GRS still shows a negative significant effect on STEM academic performance ($\beta = -.031$ and $p = .030$). The mediator CE therefore has a partial mediation on the

https://doi.org/10.33225/jbse/25.24.1101

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

correlation between GRS and STEM academic performance. These results are presented in Table 6. A further analysis using the bootstrap technique revealed that the 95% bias-corrected confidence interval for the indirect effect did not include zero (CI = –.439 to –.009), indicating a significant mediating effect of CE. Hence, H2 is supported by the data.

Table 6
Mediation Effect of CE on the Association Between GRS and STEM Academic Performance

H#	Hypothesized Path	Estimate	β	*p*	*95% CI Bootstrap BC*	
					LB	UB
H2	Direct Model GRS------> STEM.AP.	-.829	-.204	.038	-2.135	-.065
	Mediation Model GRS ----> CE ----> STEM.AP.	-.128	-.031	.030	-.439	-.009

Notes: LB= Lower Boundary; UB= Upper Boundary.

Moderating Effect of Inquiry-Based Cooperative Learning

Table 7 presents the model fit indices for the moderated mediation analysis. Model 1 examined the moderating effect of IBCL on the direct association between GRS and STEM academic performance, while Model 2 tested its moderating effect on the second part of the pathway from GRS through CE to STEM academic performance. Both models exhibited satisfactory fit, as all key indices met conventional thresholds, thus offering empirical support for the proposed moderated mediation framework.

The results in Figure 4 and Table 8 indicate a statistically significant interaction effect between IBCL and GRS on STEM academic performance ($\beta = .155$, $p < .01$), thereby supporting H3. The positive interaction coefficient suggests that IBCL mitigates the negative impact of GRS on STEM academic performance. Students exhibiting pronounced GRS show enhanced STEM academic performance when participating in higher levels of IBCL in the classroom. This indicates that IBCL plays a protective moderating role in mitigating academic disadvantages associated with stereotypes. The standardized coefficient ($\beta = .155$) indicates a small to moderate effect size, which holds practical significance, especially in educational settings that target marginalized or stereotype-vulnerable populations.

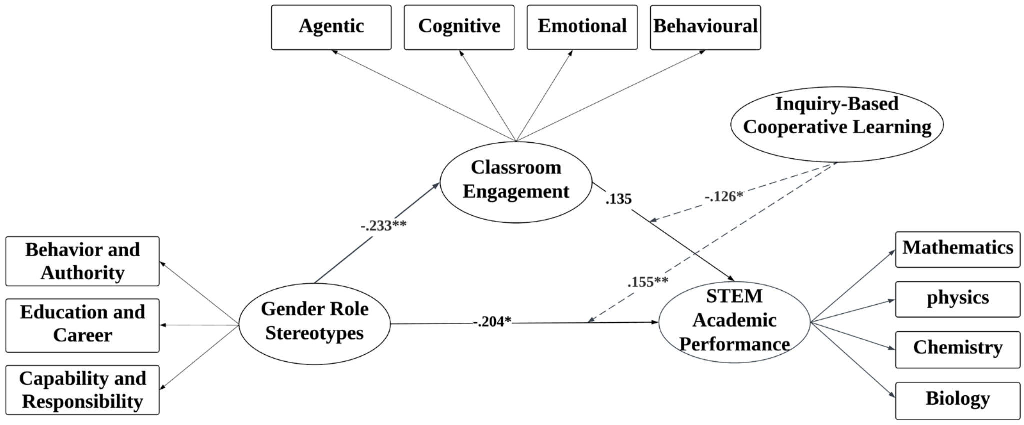
Table 7
The Structural Model Fit

Fit index	Recommended value Hair et al., 2019	Model 1	Model 2
		Moderating Effect	Moderating Effect
χ^2	Non-significant at p < .05	140.560	162.509
df	n/a	57	57
χ^2 /*df*	< 5 preferable < 3	2.466	2.851
GFI	> 0.90	.946	.938
AGFI	> 0.80	.915	.902
CFI	> 0.90	.937	.922
RMSR	< 0.10	.053	.060
RMSEA	< 0.08	.063	.071
IFI	> 0.90	.938	.924

https://doi.org/10.33225/jbse/25.24.1101

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 4
Moderated Mediation Model for the Study



In addition, the moderating effect of IBCL on the latter segment of the indirect pathway, specifically from CE to STEM academic performance, was analysed within the GRS framework. The interaction between CE and IBCL was significant ($\beta = -.126$, $p < .05$), thus supporting H4. The negative coefficient indicates that the positive influence of CE on STEM academic performance is more pronounced at lower levels of IBCL and diminishes as IBCL increases. It suggests while CE typically enhances STEM achievement, its beneficial effect decreases in environments characterized by higher levels of IBCL.

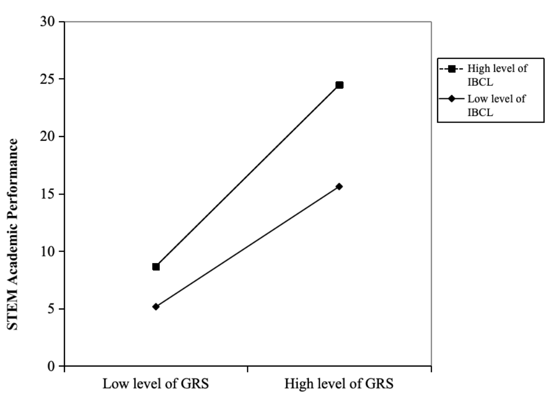
Table 8
The Summary of the Moderating Effect of Inquiry-Based Cooperative Learning

H#	Hypothesized Path	Moderated Path	B	S.E.	C.R.	β	Study Results
H3	STEM.AP. <---- GRS	STEM.AP. <---- IBCL × GRS	4.530	1.685	2.689	.155**	Supported
H4	STEM.AP. <---- CE <----GRS	STEM.AP. <---- CE × IBCL	-2.593	1.173	-2.211	-.126*	Supported

Notes: *$p < .05$; **$p < .01$.

To visually show the significantly moderating effects of IBCL previously stated, two simple slope plots were developed (Figures 5 and 6). These graphs elucidate the variation in the strength and direction of correlations with the key variables across high and low levels of IBCL.

Figure 5
Moderation of IBCL on the Association Between GRS and STEM Academic Performance

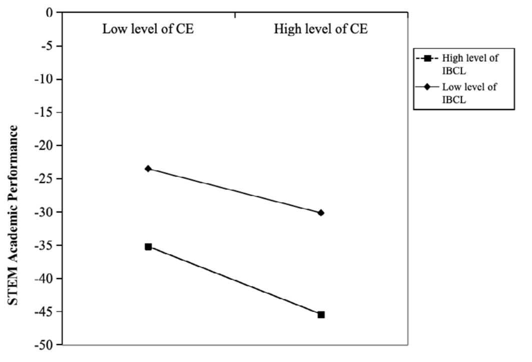


https://doi.org/10.33225/jbse/25.24.1101

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

Figure 6

Moderation of IBCL on the Indirect Path GRS → CE→ STEM Academic Performance



Discussion

Gender Role Stereotypes and STEM Academic Performance

The findings demonstrate a negative correlation between GRS and STEM academic performance among female students in underprivileged areas of China. This discovery supports earlier studies indicating that traditional gender stereotypes discourage females from performing STEM-related fields (Bagès & Martinot, 2011; Luo & Chen, 2024). Gendered perceptions of mathematical and scientific competencies frequently reduce girls' self-efficacy (Schuster & Martiny, 2017), lower their motivation (Master, 2021), and restrict their involvement in STEM fields (Tang & Zhao, 2024).

Although the direct effect of GRS on STEM academic performance was modest, it aligns with earlier studies. Rogers et al. (2021) and Charlesworth & Banaji (2022) found that implicit biases might persist even when individuals explicitly reject stereotypes, generally masked by social desirability (Agut et al., 2023). Consequently, low stereotype scores may not indicate the absence of bias, but rather unreported attitudes. Also, even minor stereotypes can make it harder for girls to get engaged in STEM and perform successfully in the long term (Master, 2021). This could clarify the reason the unfavourable effects are still prevalent.

Nonetheless, evidence from international research is mixed. Earlier research has shown that gender stereotypes in mathematics negatively affect university students' performance in the Netherlands (Marx et al., 2005), whereas in the U.S., the stereotype threat significantly lowers female students' mathematics scores in primary education (Ambady et al., 2001). However, recent studies conducted in the U.S. (Ganley et al., 2013), the Netherlands (Flore et al., 2018), and Italy (Agnoli et al., 2021) confirmed that stereotype threat did not affect the academic performance of female students in STEM fields.

A generational change may explain these inconsistencies, as Western countries progress toward gender equality, younger generations may be less vulnerable to stereotype risk. In contrast, students in economically disadvantaged communities, such as those in underdeveloped regions of China, may be more exposed to gender stereotypes. Parents in these areas have more traditional gender roles, which influence their children's perspectives (Tang & Zhao, 2024). Therefore, female students from these backgrounds may internalize gender stereotypes, resulting in self-doubt, weaker STEM persistence, and inferior math achievement.

Moreover, recent research has revealed that educators often have gendered views on mathematical ability, perceiving mathematics as intrinsically more difficult for female pupils (Terrier, 2020). Implicit biases can affect students' self-perceptions and academic achievement (Carlana, 2019). In contrast to Western nations, whose regulations and professional development initiatives seek to alleviate discrimination based on gender in education, China does not possess structured interventions or training programs to reduce teachers' stereotypes. The lack of specific policies may intensify the detrimental impact of GRS on the STEM achievements of female students.

https://doi.org/10.33225/jbse/25.24.1101

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

The Mediating Role of Classroom Engagement

This study discovered that CE significantly partially mediates the association between GRS and STEM academic performance in female students. Figure 3 shows learners with stronger stereotypes reported lowered CE, aligning with previous research findings (Li et al., 2025; Maloshonok, 2022; Musso et al., 2022; Van Houtte, 2023). Furthermore, decreased CE further contributed to a decreasing trend in STEM academic performance, which is consistent with previous evidence (Barlow & Brown, 2020; Del Toro & Wang, 2023; Guzey & Li, 2022; Murphy et al., 2019; Swargiary, 2024). The model indicates that GRS reduce girls' engagement, which in turn negatively affects their STEM academic performance in disadvantaged regions of China.

The mediating role can be interpreted in SCT (Bandura, 1986), which asserts that learners' beliefs and expectations influence their motivation and engagement, subsequently affecting academic outcomes. GRS may lower girls' self-efficacy and perceived value of tasks in STEM (Brown, 2019), resulting in less participation in the classroom. Previous research confirms that stereotypes within academic fields adversely impact motivational beliefs and emotional factors, subsequently reducing engagement (Gonzalez et al., 2020; Li et al., 2025). Evidence indicates that the endorsement of stereotypes fosters hostile classroom environments, which undermine participation and achievement, especially among marginalized groups (Del Toro & Wang, 2023; Rensaa & Fredriksen, 2022). However, the effect identified in the current study was only partially mediated, implying that stereotypes also affect STEM performance through other mechanisms beyond engagement, like limited educational aspirations or revised educator expectations. In economically disadvantaged areas of China, the absence of counter-stereotypical role models and institutional assistance likely exacerbates the direct and indirect negative effects of stereotypes on girls' STEM performance.

Moderating Effects of Inquiry-Based Cooperative Learning

This study offers new insights into the moderating effect of IBCL on the negative impact of GRS on girls' STEM academic performance. While previous studies continually highlight the benefits of cooperative and inquiry-based pedagogies for enhancing engagement and academic achievement (Gillies, 2023; Riegle-Crumb et al., 2019), limited research has explicitly studied their effectiveness in mitigating gendered barriers in education. Results from this study indicate that IBCL not just promotes collaboration and critical thinking but also serves as a protective factor that offsets the adverse effects of GRS.

Similar findings have been found in other educational settings. A quasi-experimental study conducted in Spain involving university students revealed that the Jigsaw approach to cooperative learning in mixed-gender sports sessions markedly enhanced gender equality and collaborative skills, especially for female students (García-Taibu et al., 2024). An explanation is that the interactive and problem-centred nature of IBCL challenges traditional gender imbalances in classroom participation, enabling female students to actively construct knowledge (Tam et al., 2020) and perceive various role models among peers (Li et al., 2020). This is aligned with SCT, which claims that learning is enhanced through modelling, self-belief, and social interactions (Bandura, 1986).

However, it is essential to acknowledge that the effectiveness of IBCL is not universally guaranteed in all contexts. Previous qualitative studies on flipped mathematics classrooms indicate that gender dynamics in group collaboration can occasionally reinforce, rather than mitigate, inequalities (Rensaa & Fredriksen, 2022). Male students' overconfidence and dependence on female peers frequently resulted in imbalances that weakened girls' sense of belonging and intensified their stress during collaborative tasks. The results above indicate that IBCL can function as an effective pedagogical strategy to address stereotypes; however, its effectiveness is significantly affected by classroom culture, group dynamics, and the fair allocation of participation opportunities. Most existing studies on IBCL focus on western or urban contexts, while the present study in rural China illustrates how cultural and contextual conditions mediate its effectiveness. Thereby, IBCL should not be viewed as a universally applicable solution; instead, it necessitates careful implementation and contextual adaptation to promote inclusivity and reduce gender biases.

In addition, the findings show a significant moderating effect of IBCL on the indirect pathway from GRS to STEM academic performance through CE ($\beta = -.126$, $p < .05$). While CE typically enhances STEM academic performance, the positive effect diminishes as adolescents report higher levels of IBCL. This outcome is somewhat surprising and questions the current educational reform movement, which supports active and cooperative inquiry-based learning—that is, flipped classrooms—from traditional lecture-based teaching during

https://doi.org/10.33225/jbse/25.24.1101

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

the preceding ten years. Task-oriented cooperative inquiry-based teaching strategies greatly improve STEM academic performance (Davenport Huyer et al., 2020), and previous studies have shown that active learning course designs assist either minimize or eliminate achievement gaps among underrepresented or underprepared students (Prieto-Saborit et al., 2021).

Simultaneously, it is noteworthy that our results coincide with current research (Aguillon et al., 2020; Rensaa & Fredriksen, 2022). One empirical study examined whether university students benefit from and equitably engage in active learning (Aguillon et al., 2020). Results of a large-scale active learning biology course revealed that male students engaged in most forms of classroom interaction, including post-class conversations, voluntary responses, and natural questioning, at levels higher than anticipated. In contrast, female students reported lower scientific self-efficacy and more salience for their gender. Previous studies have shown that CE is strongly influenced by self-efficacy and a sense of belonging. This may help explain why female students' participation often declines in cooperative inquiry-based classrooms.

Qualitative research in mathematics education has demonstrated similar gender dynamics within collaborative learning settings. A study on flipped classrooms indicated that female students frequently encounter power imbalances due to boys' overconfidence, thus reinforcing the perception of mathematics as a male-dominated discipline (Rensaa & Fredriksen, 2022). The reliance of unprepared male classmates on female peers for clarification can increase frustration and anxiety, whereas competent female students might experience self-doubt and heightened pressure as they undertake both teaching and learning roles. The findings suggest that collaborative methods, including flipped classrooms, may inadvertently perpetuate gender-based disparities. The persistence of these issues in Norway, a nation recognised for its high levels of gender equality, indicates that they may be exacerbated in regions with lower gender equality, such as China, where female students may face substantial difficulties in active engagement.

In addition to gender dynamics, the adverse moderating effect of IBCL could be analysed through the perspective of cognitive load theory (Sweller, 1988). Inquiry-based and cooperative learning necessitate multitasking management of various cognitive processes, including task coordination, peer communication, and problem-solving, potentially leading to an increase in additional cognitive load. In China's competitive, examination-driven educational system, excessive task demands may overload students' working memory, thus diminishing the beneficial effects of CE on academic performance. This clarifies why higher levels of IBCL may reduce the beneficial effect of CE on STEM academic achievement.

Conclusions, Limitations, and Implications

This study extends previous studies regarding the association in GRS and STEM academic achievement, showing that such stereotypes are negatively correlated with girls' STEM performance and also indirectly constrict achievement by lowering engagement in the classroom. Furthermore, the results highlight the moderating role of IBCL in the pathway between GRS and STEM academic performance. Beyond enhancing theoretical comprehension, the findings improve educational equity by identifying instructional strategies that help mitigate the adverse effects of GRS. Specifically, incorporating IBCL into educational practices provides an effective way to enable girls in impoverished areas to engage more actively in STEM learning. This research aligns with the United Nations' Sustainable Development Goals, in particular Goal 4, which focuses on ensuring inclusive and equitable quality education, and Goal 5, which aims to achieve gender equality.

This study, however, has some limitations. First, it was a cross-sectional design that might not be able to prove the causal relationship between GRS and STEM achievement. Longitudinal studies should be conducted to verify these findings in the future. Second, the findings may not be as applicable to various cultural and educational contexts as the data were gathered from a particular underprivileged area of China. To identify wider disparities, future studies should compare rural with urban educational institutions and extend the study to more varied settings. Another limitation concerns the measurement of GRS. While apparently low mean levels and modest effects, this may reflect socially acceptable responding rather than genuinely weak prejudicial attitudes. Girls in early adolescence typically temper explicit stereotyping, showing an appearance of equality while underlying stereotypes persist. Further studies are needed to consider implicit or indirect measures (e.g., resource allocation tasks, group inclusion scenarios, or implicit association tests) to elucidate these subtle biases and their influence on STEM engagement and achievement.

https://doi.org/10.33225/jbse/25.24.1101

ISSN 1648–3898 /Print/
ISSN 2538–7138 /Online/

In this study, standardised exam scores were used as a comparable and objective indicator of STEM academic performance among upper-secondary students. Nevertheless, STEM performance goes beyond test scores and includes students' practical skills, creativity, and long-term interest in STEM fields. Future studies could integrate these broader criteria to provide a more holistic evaluation of students' STEM capabilities.

Future educational reforms should give higher priority to active learning and inclusive teaching practices that promote equity among diverse student groups. Educators could consider the following approaches: (1) Reducing classroom competitiveness will help female students to relieve some of their learning stress; (2) Enhancing the self-efficacy of female students through mentoring programs and positive feedback; (3) Optimizing group cooperation models to guarantee equitable work allocation while avoiding gender-based academic dependence avoids gender-based academic dependency; (4) In China's extremely competitive education system, balancing inquiry-based learning with exam-oriented demands ensures that students acquire critical thinking abilities while also fulfilling academic evaluation criteria.

Declaration of Interest

The authors declare no competing interest.

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Received: *September 11, 2025* Revised: *October 27, 2025* Accepted: *November 12, 2025*

Cite as: Chen, P., Hassan, A. B., Hamzah, F. M., Murad, S. S., & Xu, Z. (2025). Advancing gender equity in STEM education: The role of inquiry-based cooperative learning and classroom engagement in challenging gender role stereotypes. *Journal of Baltic Science Education*, *24*(6), 1101–1116. https://doi.org/10.33225/jbse/25.24.1101

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